Generation X

System Overview

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System Overview

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- Technologies Required
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System
Overview, Supporting Data

- **Mirror Sizing**
  - "MirrorConfigurations.xls"
- **Mass and Power information**
  - "GenX_MassPowerSummary.xls"
- **Useful Web sites**
  - Access to Space at http://accesstospace.gsfc.nasa.gov/ provides launch vehicle performance information and other useful design data
  - Information related to Wiley Larson's *Space Mission Analysis and Design* (SMAD) book http://smadcd.net/

System Overview

- Four 25 m^2 X-ray telescopes, each with 100 m focal length
- Launch in 2015
- Operate in L2 orbit for thermal stability

System
Driving Requirements & Assumptions

- Thermal gradients over the entire mirror assembly must be small
- 25 m^2 of mirror area
- Pointing anywhere within ±15° of plane perpendicular to sun line
- Slew between any targets in a reasonable amount of time
  - Long dwell-time on targets (days)
  - Hours to slew between targets is OK
- Arc-second pointing
- Focal planes located 100 m from optics
- Focal planes operating at 100 mK
- L2 orbit (driven by thermal considerations)

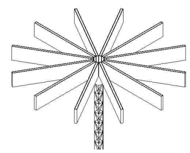
System
Driving Requirements & Assumptions

- **Instrument support**
  - Mass: 5100 kg (5000 kg optics plus 50 kg optics on a boom)
  - Power: 200 W plus possibly substantial heaters
  - Data Rate: 10 kbps
  - Deployed focal planes are in a cryostat 100 m away from optics, boom is approximately 50 kg

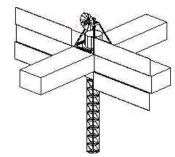
System
Options Considered

♦ Direct launch to L2

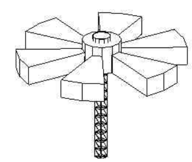
- Deployed rectangles
  - 12 segments
    - 17.7 m total diameter
    - Very difficult thermal design



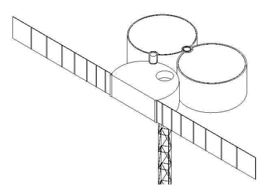
  - 4 segments
    - 9.3 m total diameter
    - Simple mechanical design
    - Gaps are a problem for the thermal design



- Deployed segments
  - Similar to Next Generation Space Telescope (NGST)
  - Only 16 m^2 optic area available
  - Gaps are a problem for the thermal design

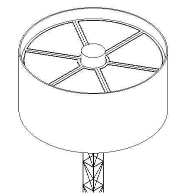


- Deployed circles
  - ✔ 2 circles, 4 m in diameter
  - Much easier for thermal design



System
Options Considered

- **Assembly near space station in Low-Earth Orbit (LEO)**
  - 5.7 m cylinder
  - 1 m central spacecraft bus
  - Align optics, check boom deployment in orbit
  - Requires substantial propulsion to L2 (~3200 m/s delta V)



- **LEO to L2 propulsion options**
  - Conventional solid/hydrazine combination
    - Much greater “wet” mass
  - Magneto-plasma dynamic system
    - Provides higher-thrust mode for 1 day to clear radiation belts
    - Higher thrust demands 10 kW of electric power
    - Lower thrust mode demands less power, provides greater efficiency
    - Longer transit time to L2
- **Spinning mirror with despun detector boom**
  - Simplifies thermal design
  - Complicates ACS

System
Selected Configuration & Rationale

♦ Direct Launch Spacecraft

- Orbit: L2, 30° halo Lissajous orbit (requires less delta V than a smaller orbit)
- Launch mass: 6400 kg including 300 kg of hydrazine
- Orbit average power: 2500 W
- Launch vehicle: Delta IV Heavy (7526 kg capability)

♦ LEO Assembled Spacecraft

- Orbit: L2, 30° halo Lissajous orbit
- Launch mass: 10,000 kg including 2800 kg of propellant (assumes specific impulse of 1000 s)
- Orbit average power: 2500 W, 10 kW peak leaving LEO
- Launch vehicle: Delta IV Heavy (23,000 kg capability--over 50% margin!)

System
Selected Configuration & Rationale

♦ LEO Assembly Scenario

- Mirror segments launched to space station orbit
- Mirror assembled and spacecraft bus attached
- Boom is deployed, and instrument focus is adjusted and verified
- Boom is retracted for transit
- High-thrust electric propulsion (~100 N) gets spacecraft clear of the radiation belts in < 1 day using 10 kW from primary battery
- Lower-thrust, higher efficiency mode of the propulsion system used for the rest of the transit to L2
- Possibility of deploying detectors during transit, but the sun attitude might not always be favorable--additional analysis required to pursue this option.

System
Technologies Required

- ♦ **X-ray mirror system**
  - Allow as much thermal gradient as possible
  - Reduce mass as much as possible

LEO Assembly Option

- ♦ **In-space assembly**
- ♦ **High specific impulse (>1000 s), higher thrust (>100 N) propulsion system**

Direct Insertion Option

- ♦ **Deployment mechanisms**
- ♦ **Adjustment mechanisms**

System Mass Summary

Spacecraft Bus Mass (kg)

	Conventional LEO to L2	High Isp to L2	Direct Insert
ACS	106	106	106
C&DH	10	10	10
Power electronics	30	30	30
Battery	33	33	33
Solar array	68	68	68
Primary Battery	0	600	0
Thermal hardware	20	20	20
RF communications	43	43	43
Balance weight	0	0	0
Bus harness	15	15	15
Bus Structure	40	100	40
Mechanisms	10	10	10
Sep system, S/C	35	35	35
Bus Total	**410**	**1070**	**410**

System Mass Summary

Propellant Sizing	Conventional LEO to L2	High Isp to L2	Direct Insert
Required delta V (m/s)	3300	3300	100
Isp (s)	290	1000	220
Mass fraction of propellant	219%	40%	5%
Dry mass (kg)	6858	6978	6068
Propellant (kg)	15044	2794	288

Mass Summary (kg)	Conventional LEO to L2	High Isp to L2	Direct Insert
Payload Total	5608	5608	5608
Bus Total	410	1070	410
Dry Propulsion Total	840	300	50
Dry Mass	6858	6978	6068
Propellant	15044	2794	288
Mass to Orbit	21902	9772	6356
Launch Vehicle Capability	23000	23000	7526
Margin (kg)	1098	13228	1170
Wet Mass Margin %	5%	58%	16%
Dry Mass Margin %	1%	41%	15%

System
Power Summary

Mission Power (W)

	Electric Prop	Operations
Payload	0	200
Payload heaters	0	2000
Payload Total	0	2200
ACS	73	73
C&DH	20	20
Power electronics	70	70
Propulsion	2000	20
Heaters	10	10
RF Comm	10	10
Harness losses	25	25
Bus Total	2208	228
Spacecraft total	2208	2428

System Requirements Verification

- Standard functional and environmental tests per GEVS
- On-orbit assembly provides the option to completely verify instrument operation prior to L2 departure

System
Additional Trades to Consider

- **Hybrid combination of conventional and electric propulsion to balance launch mass and time to L2**
- **Deployment of detector boom during transit to L2**
  - Earlier start of data collection
  - Possibility of unfavorable sun angles at times
- **Futher options and definition of detector boom**
  - Free-flying option
  - Methods to counter-act solar torque
  - Power
  - Data communications
- **Network four spacecraft together**
  - Requires links between spacecraft
  - Reduce the number of links back to Earth
  - Provide remote processing of data
  - Ease operational complexity

System
Risk Assessment

- Minimizing mirror gradients is potentially difficult and impacts the entire architecture of the spacecraft
- Detector boom has many issues besides thermal, all appear solvable
  - Power
  - Data communications
  - Solar pressure

System
Issues and Concerns

- LEO assembly has some interesting advantages, but the propulsion from LEO to L2 is a big issue. Future advances in propulsion with high specific impulse and higher thrust may make this a very economical approach. Current technology can deliver high specific impulse, but the transit time is too long (years).